THE ANATOLIAN JOURNAL OF CARDIOLOGY

Official journal of the TURKISH SOCIETY OF CARDIOLOGY

Robotic-Assisted Coronary Artery Bypass Grafting vs. Percutaneous Coronary Intervention Strategies for Ostial Left Anterior Descending Lesions

ABSTRACT

Background: The comparison of outcomes of robotic-assisted coronary artery bypass grafting (RA-CABG) vs. stenting techniques (ostial or crossover stenting) for ostial left anterior descending (LAD) artery lesions is still lacking. This retrospective study sought to determine the mid-term outcomes of RA-CABG, crossover stenting (CS), and ostial stent implantation (OSI) in patients with ostial LAD disease.

Methods: All cases were divided into 3 groups as follows: RA-CABG (group 1) (n = 157), CS (group 2) (n = 104), and OSI (group 3) (n = 178). The primary endpoint was defined as the major adverse cardiac and cerebral events (MACCE), which included cardiac death, target vessel myocardial infarction, target vessel revascularization (TVR), stroke, and stent thrombosis or symptomatic graft occlusion during follow-up. This is the first investigation comparing mid-term outcomes of RA-CABG, CS, and OSI as revascularization options for ostial LAD lesions.

Results: A total of 439 consecutive individuals [male: 341 (77.6%), mean age: 59.58 ± 9.35 years] with ostial LAD disease were included in this study. The rates of MACCE ($P = .020$ for groups 3 vs. 1; $P = .011$ for groups 3 vs. 2) and clinically driven TVR (15.7 vs. 4.5%, $P = .001$ for groups 3 vs. 1; 15.7 vs. 5.8%, $P = .014$ for groups 3 vs. 2) were notably higher in group 3 than the others. The mid-term MACCE [(adjusted hazard ratio = 2.129 [95% confidence interval: 1.360-3.334], $P = .001$)] in the overall population significantly differed between group 3 and the others.

Conclusion: The findings of the study suggest that OSI for ostial LAD lesions was associated with higher mid-term MACCE and TVR rates than revascularization with RA-CABG or CS.

Keywords: Death, left main bifurcation, major adverse cardiovascular, cerebral events, robotic-assisted coronary bypass grafting, percutaneous coronary intervention

"You never know what is enough unless you know what is more than enough."

William Blake (1757-1827)

INTRODUCTION

Atherosclerotic plaque distribution in the coronary vascular bed can take on a very intricate pattern in ostial left anterior descending (LAD) coronary artery disease.[1] Despite invasive coronary angiography identifying these diseases as simple Medina 0.1.0, it is typically difficult to predict the inclusion of distal left main coronary artery (LMCA) disease.[2-4] The complex morphological features of ostial lesions and the requirement of high technical skill make the application of interventional techniques for these lesions difficult.[2] Three revascularization options are available in the modern intervention era for these difficult anatomic lesions: surgery, crossover stenting (CS), and accurate ostial stent implantation (OSI).[1-7] The therapy of the stenosis of the ostial LAD artery is challenging owing to the complicated effects of the distal LMCA, as shown by previous studies.[1,2,5-7] Previously, OSI, CS, and other solutions have been tested. However, the findings have not been convincing owing to controversial data in the literature.[5-7] Several

ORIGINAL INVESTIGATION

Mehmet Köseoğlu[1#]
Cemalettin Akman[2#]
Ahmet Güner[2]
Koray Çiloğlu[2]
Berkay Serter[2]
Ünal Aydın[3]
Ahmet Yaşar Çizgici[2]
Ersin Kadiroğulları[3]
Taner İyigün[3]
Cemil Can[2]
Ali Rıza Demir[2]
Fatih Furkan Bedir[2]
Ezgi Gültekin Güner[2]
Abdullah Doğan[2]
Yasin Ay[3]
Fatih Uzun[2]

[1]*Department of Anestesia and Intensive Care, İstanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital, İstanbul, Türkiye*
[2]*Department of Cardiology, İstanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital, İstanbul, Türkiye*
[3]*Department of Cardiovascular Surgery, İstanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital, İstanbul, Türkiye*

Corresponding author:
Ahmet Güner
✉ ahmetguner488@gmail.com

Received: November 27, 2024
Accepted: February 25, 2025
Available Online Date: March 26, 2025

Cite this article as: Köseoğlu M, Akman C, Güner A, et al. Robotic-assisted coronary artery bypass grafting vs. percutaneous coronary intervention strategies for ostial left anterior descending lesions. *Anatol J Cardiol.* 2025;29(6):300-311.

#Mehmet Köseoğlu and Cemalettin Akman are co-first authors and equally contributed to this study.

DOI:10.14744/AnatolJCardiol.2025.5050

investigators have probed the performance of the OSI technique for ostial LAD artery disease;[5-7] however, especially in lesions that are not mapped in detail by intravascular imaging modalities, the proximal stent segment may protrude into the ostium of the side branch, cause progressive restenosis with postdilatation-induced distal LMCA injury, or may not completely cover the atherosclerotic plaque.[2] Apart from this, the side branch (mostly the left circumflex artery) may be influenced by plaque or carina shift.[1,2] Even though percutaneous coronary intervention (PCI) with the CS technique is associated with better clinical results, CS may lead to severe stenosis, occlusion, or side branch loss due to plaque or carina displacement.[1] Once this complication occurs, it inevitably requires side branch intervention or bail-out 2-stent techniques.[1,2,5-7] Furthermore, implantation of a drug-eluting stent with the CS technique into the left main without atherosclerotic disease has the potential to increase the risk of in-stent restenosis or stent thrombosis.[2] There is a dearth of large-sample size data and randomized controlled trials (RCTs) regarding PCI techniques (CS and OSI). Therefore, the European Bifurcation Club (EBC) consensus report and expert opinions emphasize that the best way to revascularize ostial LAD lesions is still a debatable issue.[1]

Conventional CABG is an efficient revascularization method for complex coronary artery disease; however, it is an extremely invasive procedure that necessitates sternum dissection to access the heart. Consequently, it causes extensive scarring, a lengthy recovery period after surgery, and morbidity.[8,9] Recent developments in coronary surgery have shown that robotic-assisted coronary artery bypass grafting (RA-CABG) has fewer short-term complications, a shorter hospital stay, and reduced rates of morbidity and mortality compared to traditional on-pump coronary artery bypass grafting.[10] Given that there is a dearth of data comparing RA-CABG with OSI and CS in terms of mid-term clinical outcomes for patients with ostial LAD disease (so-called Medina 0.1.0 left main bifurcation disease), this study aimed to compare the mid-term results of RA-CABG, CS, and OSI revascularization options in patients with this complex issue.

HIGHLIGHTS

- The present study demonstrated that revascularization with either RA-CABG or CS strategies for ostial LAD disease was associated with lower MACCE and TVR rates compared with OSI, whereas other endpoints including mortality were comparable between the 3 groups.
- Crossover stenting technique appears to be a more feasible strategy than RA-CABG in terms of length of hospital stay and several intraprocedural non-fatal major complications (i.e., pneumothorax).
- In contemporary clinical practice, for Medina 0.1.0 left main bifurcation lesions, CS may be considered a viable alternative to OSI and RA-CABG approaches in patients with SYNTAX scores < 33, and we advocate the assessment of multidisciplinary collaboration in the decision-making.
- Larger prospective studies are needed to guide the management of patients with ostial LAD lesions.

METHODS

Study Design and Population

This retrospective observational study included 439 patients who underwent PCI or RA-CABG for ostial LAD disease between January 2011 and March 2024 in our institute. Demographic information, clinical and angiographic aspects of the patients, and cardinal symptoms were collected retrospectively. Individuals diagnosed with ST-segment elevation myocardial infarction, significant LMCA disease (30-50%), incomplete revascularization, a bare metal stent, end-stage kidney disease requiring hemodialysis, cardiogenic shock status, premature discontinuation of dual antiplatelet therapy, lost to follow-up, <1-year life expectancy, and absence of medical records were excluded from the study. We allocated the patient population into 3 groups based on the proposed revascularization strategy, including RA-CABG (group 1) as surgical intervention, and PCI therapies including either CS (group 2) or OSI (group 3). The final analysis comprised 439 patients, of which 157 were assigned to group 1, 104 to group 2, and 178 to group 3. Figure 1 depicts the flow chart for patient selection and the exclusion criteria. The heart team examined the different intervention approaches (RA-CABG, CS, or OSI), considering the operators' skills, current guidelines, institutional experience, and the clinical choice reached after consulting with the patient. The patient and physician were involved in a collaborative decision-making process. Moreover, the revascularization technique or strategy employed for intervention was non-randomized and reviewed by multiple operators. It may have been chosen due to several clinical and anatomical factors that made operators feel they would be more successful with one technique over the other. This could have resulted in significant uncontrolled bias. After receiving approval from the Institutional Ethics Committee, this study followed all protocols outlined in the Declaration of Helsinki (number#2024.06-61, date: 19.11.2024). Additionally, no artificial intelligence (AI)-enabled technologies (such as llarge language models [LLM], chatbots, or image generators) were used in the production of the submitted work.

Interventional Procedures

Participating primary operators were required to perform 300 PCI per year for 3 years. The stents that were implanted with OSI or CS technique in the LMCA to LAD position were second- or third-generation DES, such as Firehawk (MicroPort Scientific Inc., Shanghai, China), Promus (Boston Scientific Inc., Galway, Ireland), Xience (Abbott Inc., Abbott Park, Illinois, USA), and Biomime (Meril Inc., Vapi, Gujarat, India), according to current recommendations from the EBC and at the operators' discretion.[11,12] The CS procedure without intravascular ultrasonography (IVUS) guidance determined the main vessel (LMCA) stent size using Finet's law.[13] Furthermore, stent enhancement is a useful imaging technique for improving operation settings, which was used in all patients.[14] The interventional cardiologist exercised their discretion in conducting IVUS assessments, by current

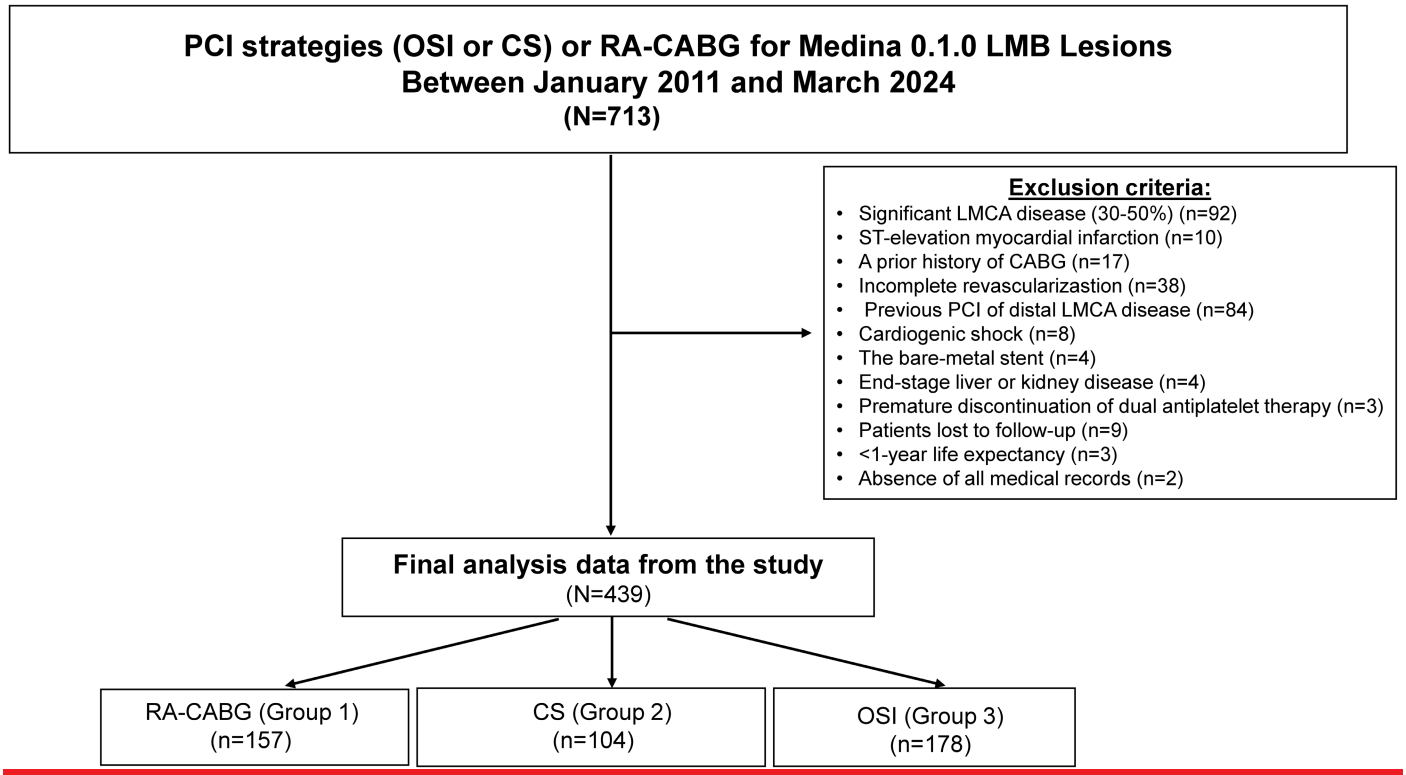

Figure 1. Flow chart for the patient selection. CABG, coronary artery bypass grafting; CS, crossover stenting; LAD, left anterior descending artery; LMB, left main bifurcation; LMCA, left main coronary artery; OSI, ostial stent implantation; RA-CABG, robotic-assisted coronary artery bypass grafting; PCI, percutaneous coronary intervention

recommendations, utilizing the 3 F Opticross coronary IVUS catheter (Boston Scientific, Fremont, CA, USA) and an automatic pull-back system (0.5 mm/sec).[15] Considerations such as stenosis severity, plaque evaluation, and ideal landing zone were taken into account when deciding between angiography and intravascular ultrasound-optimized stent placement.[16] Before and after the ostial LAD lesions had stents implanted, standard measures were taken.

Under general anesthesia, the second, fourth, and sixth intercostal gaps were used to establish 3 ports in the anterior axillary line, and the da Vinci Xi robotic system (Intuitive Surgical, Inc., Sunnyvale, CA, USA) was introduced to begin the RA-CABG procedure. A camera equipped with surgical tools was introduced into the left pleural space along with 2 lateral arms. Under constant carbon dioxide insufflation, the left internal thoracic artery (LITA) was correctly collected. The side branches of the LITA graft were harvested using bipolar cautery forceps and a low-energy monopolar electrocautery spatula. In a semi-skeletonized fashion, the LITA and its associated veins were extracted. Using a suction stabilizer (Octopus Nuvo Tissue Stabilizer, Medtronic, Minneapolis, USA), the pericardial fat was removed under endoscopic control. The LAD was then located and an optimal anastomosis site was determined. The beating heart underwent the off-pump anastomosis to the LAD. In circumstances where many veins were involved, the appropriate harvesting vessels were the great saphenous vein or the radial artery. Anastomosing the target vessel to the venous graft or radial artery followed the same procedure. Upon arrival at the intensive care unit, the patient was intubated and will be extubated within the next several hours. Following interventional procedures, the duration of dual antiplatelet therapy, including a P2Y12 receptor inhibitor, was determined depending on the clinical status of the patient, by current major cardiovascular guidelines.[9]

Clinical Assessment

Intraprocedural or in-hospital major adverse events (including death) were assessed at the time of the event or before hospital discharge. At 1, 6, and 12 months following the index procedure (RA-CABG, CS, or OSI), in addition to yearly clinic visits thereafter, all patients were routinely evaluated. Exercise stress testing, myocardial perfusion scintigraphy, or echocardiography was routinely done 6 to 12 months following the intervention to measure induced myocardial ischemia, and all patients were expected to comply with routine clinic visits. Invasive coronary angiography (coronary computed tomography angiography if needed) was performed on all patients who had clinical symptoms or instrumental evidence of myocardial ischemia during the follow-up period. Clinic visits, phone calls (for event confirmation from medical records), and referrals from other doctors all contributed to in-depth evaluations of patients' health. We also checked the National Death Database to make sure the patients' lives or deaths were accurately recorded.

Definitions and Study Outcomes

All-cause/cardiac death, clinically driven target vessel revascularization (TVR), spontaneous target vessel myocardial infarction (TVMI), stent thrombosis, symptomatic graft

occlusion, stroke, contrast-induced acute kidney injury, and major bleeding were defined according to the EXCEL trial.[17] The primary outcome was measured as major adverse cardiovascular and cerebral events (MACCE), which were cardiac death, spontaneous TVMI, TVR, stroke, and stent thrombosis or symptomatic graft occlusion under mid-term follow-up.

Statistical Analysis

Descriptive statistics were reported using mean ± standard deviation for continuous variables, and frequency with percentages for categorical data. The Shapiro–Wilk and Kolmogorov–Smirnov tests were used to determine the normality of the distribution of continuous variables. All continuous variables did not show normal distribution, and therefore non-parametric tests were used. For 2-group comparisons, continuous variables were compared across groups using the Mann–Whitney *U* test and for 3-group comparisons the Kruskal–Wallis H test was used. Simultaneously, post-hoc comparisons of the groups' means were made with the Bonferroni–Dunn test. Besides, categorical variables were contrasted using the Chi-squared and Fisher's exact tests. To identify independent predictors of MACCE in patients with ostial LAD disease, the characteristics that were discovered using univariate analyses were subsequently put into the Cox regression analysis using backward selection.

To account for treatment selection bias, the Cox proportional hazard regression model for mid-term MACCE was adjusted using the inverse probability weighted (IPW) approach to account for treatment selection bias. A multivariable logistic regression model was built to estimate the probability (propensity) of a patient being included in the OSI group versus others, given a set of measured covariates that would be predictive of the binary outcome (age, hypertension, EuroSCORE II, active side branch protection, and side branch narrowing > 50%). The standard errors of the hazard ratios from the IPW-adjusted Cox proportional hazard models are based on the robust sandwich variance estimator. Adjustment variables for both standard and IPW-adjusted Cox proportional hazard regression models were treatment (OSI), current smoker, EuroSCORE-II score, SYNTAX score, and in-hospital non-fatal major adverse events. The association between treatment and outcomes was quantified by univariate Cox regression and multiple Cox regression analyses hazard ratio (HR) and 95% confidence interval obtained by IPW-adjusted regression models. The Kaplan–Meier survival curve was used to demonstrate the cumulative incidence of MACCE, and log-rank tests were employed for group comparisons. The significance level was accepted as $P < .05$ in all statistical analyses. All statistical analyses were performed using R software v. 4.2.2 (R statistical software, Institute for Statistics and Mathematics, Vienna, Austria).

RESULTS

A total of 439 consecutive patients [male: 341 (77.6%), mean age: 59.58 ± 9.35] with ostial LAD disease were enrolled in this study. The baseline demographic, clinical, medications, and lesion characteristics of the groups are depicted in Table 1. The prevalence of older age (60.50 ± 6.30 vs. 59.04 ± 10.54 years, $P = .023$) and hypertension (81.5 vs. 62.9%, $P = 0.001$) was significantly higher in group 1 than in group 3 (Table 1). Besides, the prevalence of hypertension was significantly greater in group 1 compared to group 2 (81.5 vs. 67.3%, $P = .009$). Groups 1 and 2 had substantially higher EuroSCORE-II scores (1.13 ± 0.78 vs. 0.99 ± 0.61, $P = .003$ and 1.11 ±. 80 vs. 0.99 ± 0.61, $P = .020$, respectively) compared to group 3 (Bonferroni: group 1 > group 3) (Table 1). Other demographic, clinical, and lesion parameters were comparable between the 3 groups.

Procedural details of the MICS-CABG and PCI arms are summarized in Tables 2 and 3, respectively. The majority of cases (99.4%) utilized LITA, while a small percentage (7% of all cases) had multiarterial CABG (Table 2). In PCI groups, arterial access was predominantly femoral, and IVUS was performed in approximately one-fourth of all patients (Table 3). Besides, group 2 had a significantly higher maximum post-dilatation balloon diameter (4.70 ± 0.27 vs. 3.98 ± 0.29 mm, $P < .001$), active side branch protection rate (4.8 vs. 0%, $P = .006$), and side branch (circumflex artery) intervention (14.4 vs. 6.7%, $P = .034$) compared to group 3 (Table 3).

In-hospital complications and mid-term clinical outcomes are presented in Table 4. The length of hospital stay in group 1 was higher than in groups 2 (5.06 ± 1.36 vs 2.20 ± 2.24 days, $P < .001$) and group 3 (5.06 ± 1.36 vs 2.27 ± 1.70 days, $P < 0.001$) (Bonferroni: group 1 > group 2 and group 1 > group 3) (Table 4). The rates of MACCE (26.4 vs 15.9%, $P = .020$ for groups 3 vs 1; 26.4 vs 13.5%, $P = .011$ for groups 3 vs 2, $P = .011$ for the 3-group) and clinically driven TVR (15.7 vs 4.5%, $P = .001$ for groups 3 vs 1; 15.7 vs 5.8%, $P = .014$ for groups 3 vs 2, $P = .001$ for the 3-group) were significantly higher in group 3 than in groups 1 and 2 (Table 4). Although 3-group comparisons were similar ($P = .181$ for 3-group), group 2 had a numerically lower mortality rate than group 3 but did not differ significantly (5.8 vs 12.4%, $P = .098$) (Table 4).

In the IPW-Cox proportional hazard analysis, the mid-term MACCE [(unadjusted HR: 1.706, [95% CI: 1.115-2.611], $P = .014$ and adjusted HR (IPW) = 2.129 [95% CI: 1.360-3.334], $P = .001$)] in the overall population notably differed between the group 3 and the others (Table 5).

Kaplan–Meier analysis showed that mid-term MACCE-free survival was found to be significantly decreased in patients with the treated OSI (Log Rank $P = .032$) (Figure 2).

DISCUSSION

This is the first investigation comparing mid-term outcomes of RA-CABG, CS, and OSI revascularization options for ostial LAD disease, thereby most effectively reflecting real-world practice. The 4 major findings of the present study are: (1) the primary endpoint (MACCE) developed in 86 cases (19.6%) during the mean follow-up time of 39.41 ± 21.1 months; (2) RA-CABG and CS revascularization strategies had lower ischemia-driven combined outcome (MACCE) and TVR rates compared with the OSI under mid-term follow-up; (3) RA-CABG had longer hospital lengths of stays and a higher rate of procedural complications (i.e., pneumothorax) than

Table 1. Baseline Demographic, Clinical, and Angiographic Characteristics per Study Group

Variables	RA-CABG (Group1) (n = 157)	CS (Group2) (n = 104)	OSI (Group3) (n = 178)	*P*
Age, years	60.50 ± 6.30	59.12 ± 10.87	59.04 ± 10.54	.108 for 3-group comparison .347 for groups 1 vs. 2 **.023** for groups 1 vs. 3 .728 for groups 2 vs. 3
Gender, male	122 (77.7)	77 (74.0)	142 (79.8)	.536 for 3-group comparison .495 for groups 1 vs. 2 .644 for groups 1 vs. 3 .264 for groups 2 vs. 3
Comorbidities				
Hypertension, n (%)	128 (81.5)	70 (67.3)	112 (62.9)	**.001** for 3-group comparison **.009** for groups 1 vs. 2 **.001** for groups 1 vs. 3 .458 for groups 2 vs. 3
DM, n (%)	66 (42.0)	47 (45.2)	86 (48.3)	.515 for 3-group comparison .615 for groups 1 vs. 2 .250 for groups 1 vs. 3 .612 for groups 2 vs. 3
COPD, n (%)	20 (12.7)	13 (12.5)	19 (10.7)	.820 for 3-group comparison .955 for groups 1 vs. 2 .557 for groups 1 vs. 3 .641 for groups 2 vs. 3
CKD, n (%)	32 (20.4)	26 (25.0)	37 (20.8)	.633 for 3-group comparison .380 for groups 1 vs. 2 .927 for groups 1 vs. 3 .412 for groups 2 vs. 3
Hyperlipidemia, n (%)	97 (61.8)	65 (62.5)	112 (62.9)	.977 for 3-group comparison .907 for groups 1 vs. 2 .830 for groups 1 vs. 3 .944 for groups 2 vs. 3
Smoker, n (%)	69 (43.9)	48 (46.2)	77 (43.3)	.892 for 3-group comparison .726 for groups 1 vs. 2 .899 for groups 1 vs. 3 .637 for groups 2 vs. 3
Prior PCI, n (%)	45 (28.7)	23 (22.1)	49 (27.5)	.475 for 3-group comparison .238 for groups 1 vs. 2 .818 for groups 1 vs. 3 .315 for groups 2 vs. 3
Prior stroke, n (%)	1 (0.6)	1 (1.0)	4 (2.2)	.413 for 3-group comparison .768 for groups 1 vs. 2 .225 for groups 1 vs. 3 .655 for groups 2 vs. 3
Heart failure, n (%)	27 (17.2)	18 (17.3)	35 (19.7)	.812 for 3-group comparison .982 for groups 1 vs. 2 .562 for groups 1 vs. 3 .625 for groups 2 vs. 3
LVEF (%)	5382 ± 8.10	53.75 ± 9.70	53.21 ± 10.97	.994 for 3-group comparison .926 for groups 1 vs. 2 .947 for groups 1 vs. 3 .931 for groups 2 vs. 3
EuroSCORE II	1.13 ±.78	1.11 ±.80	0.99 ±.61	**.005** for 3-group comparison **Bonferroni: group 1 > group 3** .736 for groups 1 vs. 2 **.003** for groups 1 vs. 3 **.020** for groups 2 vs. 3

(*Continued*)

Table 1. Baseline Demographic, Clinical, and Angiographic Characteristics per Study Group (*Continued*)

Variables	RA-CABG (Group1) (n = 157)	CS (Group2) (n = 104)	OSI (Group3) (n = 178)	*P*
Clinical presentation, n (%)				
CCS	86 (54.8)	54 (51.9)	90 (50.6)	.738 for 3-group comparison .651 for groups 1 vs. 2 .441 for groups 1 vs. 3 .825 for groups 2 vs. 3
USAP	22 (14.0)	12 (11.5)	21 (11.8)	.781 for 3-group comparison .561 for groups 1 vs. 2 .545 for groups 1 vs. 3 .948 for groups 2 vs. 3
NSTEMI	49 (31.2)	38 (36.5)	67 (37.6)	.440 for 3-group comparison .371 for groups 1 vs. 2 .217 for groups 1 vs. 3 .853 for groups 2 vs. 3
Medications, n (%)				
Antiplatelet agents	157 (100.0)	104 (100.0)	178 (100.0)	-
Beta blockers	135 (86.0)	86 (82.7)	154 (86.5)	.659 for 3-group comparison .469 for groups 1 vs. 2 .888 for groups 1 vs. 3 .384 for groups 2 vs. 3
CCB	20 (12.7)	14 (13.5)	25 (14.0)	.941 for 3-group comparison .865 for groups 1 vs. 2 .726 for groups 1 vs. 3 .891 for groups 2 vs. 3
ACEI/ARB	140 (89.2)	94 (90.4)	161 (90.4)	.916 for 3-group comparison .753 for groups 1 vs. 2 .699 for groups 1 vs. 3 .986 for groups 2 vs. 3
Statin	145 (92.4)	93 (89.4)	164 (92.1)	.663 for 3-group comparison .413 for groups 1 vs. 2 .940 for groups 1 vs. 3 .440 for groups 2 vs. 3
Diuretics	29 (18.5)	21 (20.2)	40 (22.5)	.661 for 3-group comparison .729 for groups 1 vs. 2 .366 for groups 1 vs. 3 .654 for groups 2 vs. 3
Insulin	35 (22.3)	22 (21.2)	42 (23.6)	.890 for 3-group comparison .827 for groups 1 vs. 2 .777 for groups 1 vs. 3 .637 for groups 2 vs. 3
Lesion characteristics, n (%)				
Multi-vessel disease	96 (61.1)	63 (60.6)	108 (60.7)	.994 for 3-group comparison .926 for groups 1 vs. 2 .930 for groups 1 vs. 3 .987 for groups 2 vs. 3
SYNTAX score	23.54 ± 6.02	23.45 ± 6.24	23.44 ± 6.08	.968 for 3-group comparison .844 for groups 1 vs. 2 .817 for groups 1 vs. 3 .993 for groups 2 vs. 3
SYNTAX score ≤22	77 (49.0)	50 (48.1)	84 (47.2)	.974 for 3-group comparison .958 for groups 1 vs. 2 .824 for groups 1 vs. 3 .886 for groups 2 vs. 3
SYNTAX score 23-32	62 (39.5)	43 (41.3)	75 (42.1)	.833 for 3-group comparison .765 for groups 1 vs. 2 .623 for groups 1 vs. 3 .897 for groups 2 vs. 3

(*Continued*)

Table 1. Baseline Demographic, Clinical, and Angiographic Characteristics per Study Group (*Continued*)

Variables	RA-CABG (Group1) (n = 157)	CS (Group2) (n = 104)	OSI (Group3) (n = 178)	*P*
SYNTAX score ≥33	18 (11.5)	11 (10.6)	19 (10.7)	.998 for 3-group comparison .823 for groups 1 vs. 2 .818 for groups 1 vs. 3 .980 for groups 2 vs. 3
Severity of ostial LAD stenosis (%)	78.22 ± 8.95	79.29 ± 11.04	78.96 ± 13.20	.290 for 3-group comparison .285 for groups 1 vs. 2 .802 for groups 1 vs. 3 .128 for groups 2 vs. 3
LMCA stenosis < 30%	28 (17.8)	20 (19.2)	33 (18.5)	.960 for 3-group comparison .776 for groups 1 vs. 2 .867 for groups 1 vs. 3 .886 for groups 2 vs. 3

CCB, calcium channel blocker; CCS, chronic coronary syndrome; CKD, chronic kidney disease; COPD, chronic obstructive pulmonary disease; CS, crossover stenting; DM, diabetes mellitus; LAD, left anterior descending; LMCA:, left main coronary artery; LVEF, left ventricle ejection fraction; NSTEMI, non ST-elevation myocardial infarction; OSI, accurate ostial stent implantation; PCI, percutaneous coronary intervention; RA-CABG, robotic-assisted coronary artery bypass grafting.

PCI techniques; and (4) being in group 3 (OSI) was found to be one of the independent predictors of the mid-term MACCE.

The management algorithm of ostial LAD disease remains a controversial issue, especially in the rapidly developing stent technology and RA-CABG. The decision to use one revascularization technique over the other may depend on a better understanding of the lesion complexity of the atherosclerotic plaques.[2,4,7,18,19] For the PCI strategies, the prevailing option is between OSI and CS from LMCA to LAD disease.[1,2,5] The "keep it simple" 1-stent strategy has strong evidence as the "gold standard" approach for the management of most bifurcation lesions.[1,2,20] Additionally, the majority of published investigations focus on a provisional approach (CS) and OSI for ostial LAD disease.[5-7,21,22] The procedure of accurate ostial LAD stenting has some concerns. The risk of longitudinal geographic miss is particularly high.[1] Placing it too close to the circumflex artery ostium increases the risk of stent thrombosis and in-stent restenosis; meanwhile, putting it too far away raises the risk of missing the sick ostium. Spasm, dissection, or displacement of the distal LMCA bifurcation carina or plaque into the circumflex artery ostium can happen even with the best stent placement.[2,5] Hence, the optimal stent positioning for the OSI technique is a quite challenging issue.[2] Additionally, the concern with the CS technique is the possibility of plaque shifting to the side branch or the need for intervention for the side branch and the procedure being

Table 2. Procedure Details of RA-CABG Group

Variables	RA-CABG (Group 1) (n = 157)
LITA use, n (%)	156 (99.4)
Radial artery graft use, n (%)	9 (5.7)
Single arterial greft use, n (%)	145 (92.4)
Multiarterial CABG, n (%)	11 (7.0)
Saphenous venous grafts, n (%)	72 (45.9)
Number of total arterial greft	1.06 ±. 27
Number of total greft	2.01 ± 1.02
Conversion to full sternotomy, n (%)	10 (6.4)

CABG, coronary bypass grafting; LITA, left internal thoracic artery; RA-CABG, robotic-assisted coronary artery bypass grafting.

Table 3. Procedural Characteristics of the PCI Groups

Variables	CS (Group 2) (n = 104)	OSI (Group 3) (n = 178)	*P*
Access site, n (%)			
Femoral	100 (96.2)	169 (94.9)	.640
Radial	4 (3.8)	9 (5.1)	.773
IABP support, n (%)	7 (6.7)	4 (2.2)	.106
Utilization of IVUS, n (%)	32 (30.8)	43 (24.1)	.613
Stent diameter, mm	3.78 ± 0.26	3.72 ± 0.46	.514
Stent length, mm	23.75 ± 7.04	23.01 ± 5.14	.910
LCx narrowing > 50%, n (%)	15 (14.4)	12 (6.7)	**.034**
Maximum POT balloon diameter, mm	4.70 ± 0.27	3.98 ± 0.29	**< .001**
Active SB protection, n (%)	5 (4.8)	0 (0.0)	**.006**
SB intervention, n (%)	7 (6.7)	8 (4.5)	.423
Performed RA, n (%)	3 (2.9)	3 (1.7)	.673
Performed IVL, n (%)	2 (1.9)	3 (1.7)	1.00
Thrombus aspiration, n (%)	2 (1.9)	7 (3.9)	.493
Tirofiban use during PCI, n (%)	8 (7.7)	14 (7.9)	1.00
Contrast media volume (mL)	140.17 ± 67.23	125.78 ± 61.33	.112
Fluoroscopy time, minute	15.04 ± 6.04	15.41 ± 5.07	0.095

Bold indicates significance level at *P* < .05.
CS, crossover stenting; IABP, intra-aortic balloon pump; IVL, intravascular lithotripsy; IVUS, intravascular ultrasound; LCx, left circumflex; LITA, left internal thoracic artery; OSI, ostial stent implantation; POT, proximal optimization technique; RA, rotational atherectomy; SB, side branch.

Table 4. In-Hospital and Mid-term Clinical Outcomes per Study Group

Variables	RA-CABG (Group 1) (n = 157)	CS (Group 2) (n = 104)	OSI (Group 3) (n = 178)	*P*
In-hospital outcomes, n (%)				
All-cause-death	1 (0.6)	1 (1.0)	2 (1.1)	1.00 for 3-group comparison 1.00 for groups 1 vs. 2 1.00 for groups 1 vs. 3 1.00 for groups 2 vs. 3
ST or SGO	1 (0.6)	1 (1.0)	1 (0.6)	0.872 for 3-group comparison 1.00 for groups 1 vs. 2 1.00 for groups 1 vs. 3 1.00 for groups 2 vs. 3
TVMI	4 (2.5)	1 (1.0)	2 (1.1)	.490 for 3-group comparison .651 for groups 1 vs. 2 0.425 for groups 1 vs. 3 1.00 for groups 2 vs. 3
Stroke	3 (1.9)	0 (0.0)	2 (1.1)	.363 for 3-group comparison .278 for groups 1 vs. 2 .668 for groups 1 vs. 3 .533 forgroups 2 vs. 3
AKI requiring RRT	3 (1.9)	2 (1.9)	3 (1.7)	.984 for 3-group comparison 1.00 for groups 1 vs. 2 1.00 for groups 1 vs. 3 1.00 for groups 2 vs. 3
Prolonged endotracheal intubation (> 24 hours)	1 (0.6)	2 (1.9)	3 (1.7)	.609 for 3-group comparison .565 for groups 1 vs. 2 .626 for groups 1 vs. 3 1.00 for groups 2 vs. 3
Pneumothorax	7 (4.5)	0 (0.0)	0 (0.0)	–
Superficial wound infections	2 (1.3)	1 (1.0)	0 (0.0)	.341 for 3-group comparison 1.00 for groups 1 vs. 2 .219 for groups 1 vs. 3 .369 for groups 2 vs. 3
TIMI-major bleeding	6 (3.8)	4 (3.8)	5 (2.8)	.846 for 3-group comparison 1.00 for groups 1 vs. 2 .761 for groups 1 vs. 3 .730 for groups 2 vs. 3
Non-fatal MAE	16 (10.2)	7 (6.7)	11 (6.2)	.354 for 3-group comparison 1.00 for groups 1 vs. 2 1.00 for groups 1 vs. 3 1.00 for groups 2 vs. 3
Hospital LOS, days	5.06 ± 1.36	2.20 ± 2.24	2.27 ± 1.70	**< 0.001** for 3-group comparison **Bonferroni: group 1 > group 2 and group 1 > group 3** **< .001** for groups 1 vs. 2 **< .001** for groups 1 vs. 3 **< .001** for groups 2 vs. 3
Follow-up time, months	39.88 ± 16.76	38.81 ± 25.17	39.35 ± 21.71	.677 for 3-group comparison .297 for groups 1 vs. 2 .940 for groups 1 vs. 3 .573 for groups 2 vs. 3
Mid-term outcomes, n (%)				
MACCE	25 (15.9)	14 (13.5)	47 (26.4)	**.011** for 3-group comparison .585 for groups 1 vs. 2 **.020** for groups 1 vs. 3 **.011** for groups 2 vs. 3
Cardiac death	12 (7.6)	4 (3.8)	17 (9.6)	.215 for 3-group comparison .294 for groups 1 vs. 2 .536 for groups 1 vs. 3 .100 for groups 2 vs. 3

(*Continued*)

Table 4. In-Hospital and Mid-term Clinical Outcomes per Study Group (*Continued*)

Variables	RA-CABG (Group 1) (n = 157)	CS (Group 2) (n = 104)	OSI (Group 3) (n = 178)	*P*
TVMI	13 (8.3)	5 (4.8)	18 (10.1)	.293 for 3-group comparison .327 for groups 1 vs. 2 .578 for groups 1 vs. 3 .175 for groups 2 vs. 3
Clinically driven TVR	7 (4.5)	6 (5.8)	28 (15.7)	**.001** for 3-group comparison .773 for groups 1 vs. 2 **.001** for groups 1 vs. 3 **.014** for groups 2 vs. 3
ST or SGO	2 (1.3)	2 (1.9)	6 (3.4)	.843 for 3-group comparison .624 for groups 1 vs. 2 .878 for groups 1 vs. 3 .714 for groups 2 vs. 3
Stroke	1 (0.6)	1 (1.0)	4 (2.2)	.413 for 3-group comparison 1.00 for groups 1 vs. 2 .376 for groups 1 vs. 3 .655 for groups 2 vs. 3
All-cause death	14 (8.9)	6 (5.8)	22 (12.4)	.181 for 3-group comparison .477 for groups 1 vs. 2 .310 for groups 1 vs. 3 .098 for groups 2 vs. 3

Bold indicates significance level at $P < 0.05$.
AKI, acute kidney injury; CS, crossover stenting; LOS, length of stay; MACCE, major adverse cardiovascular and cerebral event; MAE, major adverse events; MI, myocardial infarction; OSI, ostial stent implantation; RA-CABG, robotic-assisted coronary artery bypass grafting; RRT, renal replacement therapy; ST, stent thrombosis; SGO, symptomatic graft occlusion; TVMI, target vessel myocardial infarction; TVR, target vessel revascularization.

converted to a bail-out 2-stent technique. Several investigators reported that the bail-out 2-stent procedure has a high incidence of poor clinical outcomes.[2,5,7] In the past 10 years, RA-CABG may be considered a promising intervention due to all these drawbacks of PCI techniques for ostial LAD disease.[3,10,19] The RA-CABG and other minimally invasive coronary surgery options have grown in popularity due to the projected lower mortality, perioperative morbidity, and short-term major adverse events compared to conventional CABG.[3,10,18,19] The other major advantages of RA-CABG over conventional CABG are: (1) a shorter length of hospital stay, (2) a lower incidence of acute care facility discharge, (3) skeletonized LITA, (4) tiny incision, (5) faster recovery, and (6) good cosmetic effect [3]. Several studies regarding the comparison of minimally invasive approaches including RA-CABG vs conventional CABG in patients with coronary artery disease have been tested in recent years.[18,23-26] However, a limited number of investigations were reported regarding the mid-term outcomes of patients with isolated LAD disease who underwent RA-CABG or PCI with DES,[3,4] and there is no data in the literature comparing RA-CABG with PCI strategies (CS or OSI) for ostial LAD disease. Hence, we believe that the present study provides novel insights to clarify this uncertainty.

We observed that MACCE and clinically driven TVR occurred more frequently in the OSI group compared to the RA-CABG and CS groups. However, other endpoints were comparable between the groups. Several investigators previously indicated that minimally invasive surgical approaches and PCI had no significant difference in the combined ischemia-driven outcomes in patients with isolated LAD lesions (ostial or proximal localization) under mid- to long-term follow-up.[4,27,28] Whereas, several investigators reported that minimally invasive surgical approaches, including RA-CABG, improve clinical symptoms (angina pectoris) and reduce the

Table 5. Univariate Cox Regression and Multiple Cox Regression Analysis Predicting Mid-term Primary Endpoint (MACCE)

Parameters	Unadjusted HR	95% CI	*P*	Adjusted HR (IPW)	95% CI	*P*
Being in group 3 (OSI)	1.706	1.115-2.611	.014	2.129	1.360-3.334	**.001**
Current smoker	0.666	0.424-1.047	.078	0.913	0.567-1.470	.709
EuroSCORE-II score	2.108	1.838-2.419	< .001	1.718	1.427-2.070	**< .001**
SYNTAX score	1.158	1.114-1.203	< .001	1.091	1.045-1.139	**< .001**
In-hospital non-fatal MAE	4.313	2.474-7.517	< .001	1.758	0.962-3.210	.066

Bold indicates significance level at $P < .05$.
CI, confidence interval; EuroSCORE, European system for cardiac operative risk evaluation; HR, hazard ratio; IPW, inverse probability-weighted; MACCE, major adverse cardiovascular and cerebral event; MAE, major adverse events; OSI, accurate ostial stent implantation.

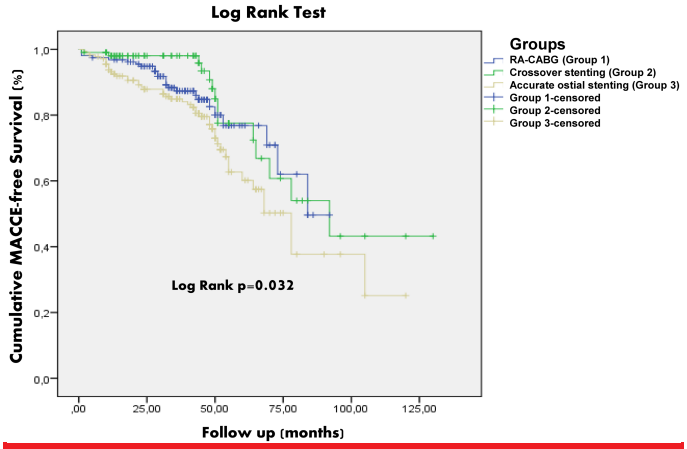

Figure 2. Kaplan–Meier survival analysis for primary endpoint (MACCE) under mid-term follow-up. RA-CABG, robotic-assisted coronary artery bypass grafting; MACCE, major adverse cardiovascular and cerebral events.

rate of ischemia-driven outcomes and TVR compared to PCI in patients with isolated proximal LAD stenosis.[3,29] The several concerns in all these publications should be addressed: (1) LAD lesions were revascularized with minimally invasive direct coronary bypass grafting (not RA-CABG), (2) bare-metal stents or first-generation drug-eluting stents were used with PCI in several investigations, and (3) most studies did not include specific analysis for ostial LAD lesions.[3-7,18,19,27-30] Accurate OSI and CS techniques are considered the 2 essential PCIs for ostial LAD lesions.[1,2,5] Recently, several publications have demonstrated that the CS technique was associated with lower long-term combined outcomes, TVR, and mortality rates compared with OSI in patients with ostial LAD disease.[5,21,31] Likewise, a recent meta-analysis showed that CS from LAD to LMCA emerges as a promising revascularization strategy for ostial LAD lesions.[32] Conversely, Soylu et al[7] suggest that the PCI with OSI was associated with better long-term major adverse cardiac events compared to CS.

The major drawback of a minimally invasive approach (RA-CABG) is its limited indication for revascularization. Specifically, young patients with proximal LAD disease, chronic total occlusion of the ostial LAD, advanced age or comorbidities (e.g., end-stage chronic kidney disease) with ostial LAD disease, and (4) special situations in which patients decline conventional CABG with sternotomy despite the heart team's favorable opinion regarding the benefits of conventional CABG over PCI. These concerns prevent the clinical outcomes of this surgical approach (RA-CABG) from being generalized to all coronary artery lesions.[10,19] Additionally, the lack of RCTs, the paucity of large-scale prospective studies comparing PCI techniques for ostial LAD lesions, and the quite low use of intravascular imaging tools in published studies prevent a strong conclusion regarding which PCI technique would have better clinical outcomes than other techniques. The best way to solve this uncertainty is for prospective studies with routine use of intravascular imaging to decide which revascularization strategy would improve the clinical outcomes of patients with ostial LAD disease.

SYNTAX score and EuroSCORE-II are well-established scoring systems for predicting preoperative adverse events.[33-37] Likewise, in the present study, we found these scores to be independent predictors of the mid-term MACCE.

Study Limitations

Several limitations should be addressed in the present study. First of all, the non-RCT and retrospective design could be considered a major limitation that might have introduced selection bias. Therefore, we used an IPW-Cox method to minimize such a possibility. Second, this was a single-center study; therefore, these results should be cautiously generalized to other centers. Third, the sample size of the study was relatively small. However, it is still remarkable for its size within each group. Fourth, the relatively low rate of imaging in the current complex PCI climate is also a significant limitation. Fifth, preoperative coronary computed tomography angiography for LAD assessment was not routinely performed. Lastly, the determination of the severity of lesions through quantitative coronary angiographic study and regular physiological examinations is lacking.

CONCLUSION

In conclusion, for patients with ostial LAD lesions, the CS and RA-CABG strategies may result in fewer mid-term combined ischemia-driven outcomes (MACCE) and clinically driven TVR rates. However, there is no appreciable difference in mid-term survival for all revascularization options. Although RA-CABG is less invasive and has better clinical outcomes than other surgical revascularization options, PCI with CS has comparable ischemia-driven outcomes and more favorable outcomes in terms of length of hospital stay and procedural complications compared to RA-CABG. Therefore, we advocate revascularization with the CS strategy in Medina 0.1.0 left main bifurcation patients with low and intermediate SYNTAX scores and emphasize the evaluation of the multidisciplinary cardiac team in the decision-making process. Our findings provide more accurate and generalizable estimates with new insights regarding patients with ostial LAD lesions. Nevertheless, large-scale prospective RCTs with the routine use of intravascular imaging tools are warranted to address the best revascularization option in complex groups of patients.

Ethics Committee Approval: This study was approved by the Ethics Committee of İstanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital (Approval No: 2024.06-61, Date: 19.11.2024).

Informed Consent: Due to the retrospective nature of the study, informed consent is not required.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – M.K., C.A., A.G.; Design –C.A., M.K., K.Ç., Supervision – F.U. Y.A.; Resources –B.S., Ü.A., A.Y.Ç., E.K., T.İ.; Materials –C.C., A.R.D., F.F.B., E.G.G.; Data Collection and/or

Processing – A.D., C.C., C.A., B.S., K.Ç., E.G.G., Analysis and/or Interpretation – A.G. Literature Search – C.A, M.K., A.D. K.Ç.,B.S.; Writing – M.K., C.A., A.G. Critical Review – Y.A., F.U.

Declaration of Interests: The authors have no conflict of interests to declare.

Funding: The authors declare that this study has received no financial support.

REFERENCES

1. Burzotta F, Lassen JF, Lefèvre T, et al. Percutaneous coronary intervention for bifurcation coronary lesions: the 15th consensus document from the European Bifurcation Club. *EuroIntervention*. 2021;16(16):1307-1317. [CrossRef]
2. Kovacevic M, Burzotta F, Srdanovic I, Petrovic M, Trani C. Percutaneous coronary intervention to treat unprotected left main: common (un-answered) challenges. *Kardiol Pol*. 2022;80(4):417-428. [CrossRef]
3. Li S, Zhang H, Xiao C, Wang R, Wu Y. Robotically assisted coronary artery bypass graft surgery versus drug-eluting stents for patients with stable isolated proximal left anterior descending disease. *J Card Surg*. 2021;36(6):1864-1871. [CrossRef]
4. Patel NC, Hemli JM, Seetharam K, et al. Minimally invasive coronary bypass versus percutaneous coronary intervention for isolated complex stenosis of the left anterior descending coronary artery. *J Thorac Cardiovasc Surg*. 2022;163(5):1839-1846.e1. [CrossRef]
5. Güner A, Akman C, Çiloğlu K, et al. Long-term evaluation of revascularization strategies for medina 0.1.0 left main bifurcation lesions: the LM-CROSSOVER registry. *Angiology*. 2023 November 1:33197231213194. [CrossRef] [online ahead of print].
6. Lee HM, Nam CW, Cho YK, et al. Long-term outcomes of simple crossover stenting from the left main to the left anterior descending coronary artery. *Korean J Intern Med*. 2014;29(5):597-602. [CrossRef].
7. Soylu K, Yıldırım U, Nasifov M, et al. Evaluation of long-term outcomes of crossover or focal ostial stenting of left anterior descending artery ostial stenosis. *Anatol J Cardiol*. 2022;26(11):827-831. [CrossRef].
8. Davidson LJ, Cleveland JC, Welt FG, et al. A practical approach to left main coronary artery disease: JACC state-of-the-art review. *J Am Coll Cardiol*. 2022;80(22):2119-2134. [CrossRef].
9. Neumann FJ, Sousa-Uva M, Ahlsson A, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. *Eur Heart J*. 2019;40(2):87-165. [CrossRef].
10. Gaudino M, Bakaeen F, Davierwala P, et al. New strategies for surgical myocardial revascularization. *Circulation*. 2018;138(19):2160-2168. [CrossRef].
11. Burzotta F, Lassen JF, Banning AP, et al. Percutaneous coronary intervention in left main coronary artery disease: the 13th consensus document from the European Bifurcation Club. *EuroIntervention*. 2018;14(1):112-120. [CrossRef]
12. Albiero R, Burzotta F, Lassen JF, et al. Treatment of coronary bifurcation lesions, part I: implanting the first stent in the provisional pathway. The 16th expert consensus document of the European Bifurcation Club. *EuroIntervention*. 2022;18(5):e362-e376. [CrossRef]
13. Finet G, Derimay F, Motreff P, et al. Comparative analysis of sequential proximal optimizing technique versus kissing balloon inflation technique in provisional bifurcation stenting: fractal coronary bifurcation bench test. *JACC Cardiovasc Interv*. 2015;8(10):1308-1317. [CrossRef]
14. Burzotta F, Louvard Y, Lassen JF, et al. Percutaneous coronary intervention for bifurcation coronary lesions using optimised angiographic guidance: the 18th consensus document from the European Bifurcation Club. *EuroIntervention*. 2024;20(15):e915-e926. [CrossRef]
15. Lotfi A, Jeremias A, Fearon WF, et al. Expert consensus statement on the use of fractional flow reserve, intravascular ultrasound, and optical coherence tomography: a consensus statement of the society of cardiovascular angiography and interventions. *Catheter Cardiovasc Interv*. 2014;83(4):509-518. [CrossRef]
16. Chieffo A, Latib A, Caussin C, et al. A prospective, randomized trial of intravascular-ultrasound guided compared to angiography guided stent implantation in complex coronary lesions: the AVIO trial. *Am Heart J*. 2013;165(1):65-72. [CrossRef]
17. Kappetein AP, Serruys PW, Sabik JF, et al. Design and rationale for a randomised comparison of everolimus-eluting stents and coronary artery bypass graft surgery in selected patients with left main coronary artery disease: the EXCEL trial. *EuroIntervention*. 2016;12(7):861-872. [CrossRef]
18. Cain MT, Joyce DL, Szabo A, et al. Reduced morbidity and mortality associated with minimally invasive single-vessel coronary artery bypass compared with conventional sternotomy. *Ann Surg*. 2023;277(5):e1176-e1183. [CrossRef]
19. Dokollari A, Sicouri S, Erten O, et al. Long-term clinical outcomes of robotic-assisted surgical coronary artery revascularisation. *EuroIntervention*. 2024;20(1):45-55. [CrossRef]
20. Hildick-Smith D, Egred M, Banning A, et al. The European bifurcation club Left Main Coronary Stent study: a randomized comparison of stepwise provisional vs. systematic dual stenting strategies (EBC MAIN). *Eur Heart J*. 2021;42(37):3829-3839. [CrossRef]
21. Rigatelli G, Zuin M, Baracca E, et al. Long-term clinical outcomes of isolated ostial left anterior descending disease treatment: ostial stenting versus left main cross-over stenting. *Cardiovasc Revasc Med*. 2019;20(12):1058-1062. [CrossRef]
22. Kishi K, Kimura T, Morimoto T, et al. Sirolimus-eluting stent implantation for ostial left anterior descending coronary artery lesions: three-year outcome from the j-Cypher Registry. *Circ Cardiovasc Interv*. 2011;4(4):362-370. [CrossRef]
23. Sorm Z, Harrer J, Voborník M, Cermáková E, Vojácek J. Early and long-term results of minimally invasive coronary artery bypass grafting in elderly patients. *Kardiol Pol*. 2011;69(3):213-218.
24. Ushioda R, Hirofuji A, Yoongtong D, et al. Multi-vessel coronary artery grafting: analyzing the minimally invasive approach and its safety. *Front Cardiovasc Med*. 2024;11:1391881. [CrossRef]
25. Edwards J, Binongo J, Mullin B, et al. Intensive Care Unit bypass for robotic-assisted single-vessel coronary artery bypass grafting. *Ann Thorac Surg*. 2023;115(2):511-517. [CrossRef]
26. Sampon F, Ter Woorst J, Dekker L, Akca F. Thoracoscopic-assisted, minimally invasive versus off-pump bypass grafting for single vessel coronary artery disease - A propensity matched analysis. *Int J Cardiol*. 2024;409:132175. [CrossRef]
27. Choi W, Chang HW, Kang SH, et al. Comparison of minimally invasive direct coronary artery bypass and percutaneous coronary intervention using second-generation drug-eluting stents for coronary artery disease-propensity score-matched analysis. *Circ J*. 2019;83(7):1572-1580. [CrossRef]
28. Etienne PY, D'hoore W, Papadatos S, et al. Five-year follow-up of drug-eluting stents implantation vs minimally invasive direct coronary artery bypass for left anterior descending artery disease: a propensity score analysis. *Eur J Cardiothorac Surg*. 2013;44(5):884-890. [CrossRef]

29. Aziz O, Rao C, Panesar SS, et al. Meta-analysis of minimally invasive internal thoracic artery bypass versus percutaneous revascularisation for isolated lesions of the left anterior descending artery. *BMJ*. 2007;334(7594):617. [CrossRef]
30. Patel AJ, Yates MT, Soppa GK. What is the optimal revascularization technique for isolated disease of the left anterior descending artery: minimally invasive direct coronary artery bypass or percutaneous coronary intervention? *Interact Cardiovasc Thorac Surg*. 2014;19(1):144-148. [CrossRef]
31. Yang ZK, Hu J, Ding FH, Ni JW, Zhang RY, Shen WF. One-year outcome of single-stent crossover versus accurate ostial stenting for isolated left anterior descending ostial stenosis. *Coron Artery Dis*. 2022;31(1):e67-e72. [CrossRef]
32. Shi H, Hyasat K, Deshmukh T, et al. Optimal percutaneous treatment approach to unprotected ostial left anterior descending artery disease: a meta-analysis and systematic review. *Heart Lung Circ*. 2024;33(8):1123-1135. [CrossRef]
33. Çizgici AY, Güner A, Alizade E, et al. Cardiovascular outcomes of complex bifurcation lesions following double kissing crush or nano-crush techniques: the multicenter EVOLUTE-CRUSH V study. *Catheter Cardiovasc Interv*. 2024;104(2):191-202. [CrossRef].
34. Uzun F, Güner A, Demirci G, et al. Comparison of long-term outcomes of double kissing crush versus T and minimal protrusion techniques in complex bifurcation lesions: the evolute-crush II registry. *Catheter Cardiovasc Interv*. 2024;103(4):511-522. [CrossRef]
35. Güner A, Uzun F, Çizgici AY, et al. Long-term cardiovascular outcomes after mini-crush or T and minimal protrusion techniques in complex bifurcation lesions: the evolute-crush III study. *Coron Artery Dis*. 2024;35(8):641-649. [CrossRef]
36. Uzun F, Güner A, Serin E, et al. Mini-crush or nano-crush stenting technique for complex coronary bifurcation lesions: the multicenter MINANO registry. *Can J Cardiol*. 2025:S0828-282X(25)00015-7. [CrossRef] [online ahead of print]
37. Fukui T, Uchimuro T, Takanashi S. EuroSCORE II with SYNTAX score to assess risks of coronary artery bypass grafting outcomes. *Eur J Cardiothorac Surg*. 2015;47(1):66-71. [CrossRef]